Debating over heterogeneous descriptions

M. Morge, J.-C. Routier

Debating over heterogeneous descriptions

M. Morge* Jean-Christophe Routier**
morge@di.unipi.it routier@lifl.fr

*Dipartimento di Informatica
University of Pisa
Largo B. Pontecorvo, 3 I-56127 Pisa, Italy

** LIFL - USTL
Batiment M3 - F-59655 VILLENEUVE D'ASCQ Cedex FRANCE

Résumé :
L'hétérogénéité sémantique des ontologies est un obstacle majeur à l'interopérabilité dans les systèmes multi-agents ouverts. Nous proposons dans cet article un cadre formel pour que les agents débattent à partir de terminologies hétérogènes. À cette intention, nous proposons un cadre de représentation argumentatif qui permet de gérer des descriptions conflictuelles. Nous présentons également un modèle d'agents qui expliquent les termes qu'ils utilisent et prennent en compte les explications de leurs interlocuteurs. Finalement, nous proposons un système dialectique permettant aux agents de particper à un dialogue pour atteindre un accord sur une terminologie commune.

Mots-clés : Intelligence artificielle, Système Multi-Agents, Dialogue, Argumentation, Ontologie, Logique de Description

Abstract:
A fundamental interoperability problem is caused by the semantic heterogeneity of agents'ontologies in open multi-agent systems. In this paper, we propose a formal framework for agents debating over heterogeneous terminologies. For this purpose, we propose an argumentation-based representation framework to manage conflicting descriptions. Moreover, we propose a model for the reasoning of agents where they justify the description to which they commit and take into account the description of their interlocutors. Finally, we provide a dialectical system allowing agents to participate in a dialogue in order to reach an agreement over heterogeneous ontologies.

Keywords: Artificial Intelligence, Multi-agent system, Dialogue, Argumentation, Ontology, Description logic

1 Introduction

Traditionally, ontologies have been used to achieve semantic interoperability between applications, such as software agents. In open systems that agents can dynamically join or leave, a fundamental interoperability problem is caused by the semantic heterogeneity of agents at the knowledge level. The current approaches such as standardization, adopted by [5], and ontology alignment, considered by [4], are not suitable in open systems. Since standardization requires that all parties involved reach a consensus on the ontology, this idea seems very unlikely. On the other hand, ontology alignment uses some mappings to translate messages. However, we do not know *a priori* which ontologies should be mapped within an open multi-agent system.

Argumentation is a promising approach for (1) reasoning with inconsistent information, (2) facilitating rational interaction, and (3) resolving conflicts. In this paper, agents have their own definitions of concepts and they discover through the dialogue whether or not they share these definitions. If not, they are able to learn the definition of their interlocutor. For this purpose, we extend the formal framework for inter-agents dialogue based upon the argumentative techniques proposed by [7]. (1) We propose here an argumentation-based representation framework, offering a way to manage contradictory concept definitions and assertions. (2) We propose a model of agent reasoning to put forward some representations and take into account the representations of their interlocutors. (3) Finally, we provide a dialectical system in which a protocol enables two agents to reach an agreement about their representations.

Paper overview. Section 2 introduces the example of dialogue that will illustrate our framework. In Section 3, we provide the syntax and the semantics of the description logic which is adopted in this paper. Section 4 presents the argumentation framework that manages interaction between conflicting representations. In accordance with this background, Section 5 describes our agent model. In Section 6, we define the formal area for agents debate. Section 7 describes the protocol used to reach an agreement. Section 8 presents some related works. Section 9 draws some conclusions and future works.

2 Natural language

[11] defines a dialogue as a coherent sequence of moves from an initial situation to reach the goal of participants. For instance, the goal of a dialogue may consist in resolving a conflict about a representation.

Before we start to formalize such dialogues, let us first discuss the following natural language dialogue example between a customer and a service provider :

1. customer : Do you know free software to view my PDF ?
2. provider : acrobat is free software.
3. customer : Why is it a free software ?
4. provider : acrobat is free because it is a freeware.
5. customer : In my humble opinion, acrobat is not a free software.
6. provider : Why is it not free software ?
7. customer : Since acrobat is freeware, it is not free software.
8. provider : OK, however xpdf is free software.
9. customer : Why is it free software ?
10. provider : xpdf is free software because it is opensource.
11. customer : Why is it opensource ?
12. provider : xpdf is opensource because it is copyleft.
13. customer : OK, I will consider xpdf.

In this dialogue, two participants share the concept “free”. However, their definitions are divergent. On one side, the customer considers free software as non-proprietary software. On the other side, the service provider considers free software as a zero price software. This dialogue reveals the conflict in the definitions of this concept and resolves it. Throughout the following we will assume the service provider gives priority to the customer’s concepts.

3 Description Logic

In this section, we provide the syntax and the semantics for the well-known $\mathcal{ALC}$ language proposed by [8] and which is adopted in the rest of the paper.

The data model of a knowledge base (KBase, for short) can be expressed by means of the Description Logic (DL, for short) which has a precise semantic and effective inference mechanisms. Moreover, most ontologies markup languages (e.g. OWL) are partly founded on DL. The syntax of the representation adopted here is taken from standard constructors proposed in the DL literature. In $\mathcal{ALC}$, concepts, denoted $C, D, \ldots$ are interpreted as unary predicates and primitive roles, denoted $R, S, \ldots$, as binary predicates. We call description a complex concept which can be built using constructors. The syntax of $\mathcal{ALC}$ is defined by the following BNF definition : $C \rightarrow \top|\bot|C|\neg C|C \sqcup D|C \sqcap D|\exists R.C|\forall R.C$. The semantics is defined by an interpretation $\mathcal{I} = (\Delta^{\mathcal{I}}, \cdot^{\mathcal{I}})$, where $\Delta^{\mathcal{I}}$ is the non-empty domain of the interpretation and $\cdot^{\mathcal{I}}$ stands for the interpretation function.

A KBase $\mathcal{K} = \langle \mathcal{T}, \mathcal{A} \rangle$ contains a T-box $\mathcal{T}$ and an A-box $\mathcal{A}$. The T-box includes a set of concept definition ($C \equiv D$) where C is the concept name and D is a description given in terms of the language constructors. The A-box contains extensional assertions on concepts and roles. For example, a (resp. (a, b)) is an instance of the concept C (resp. the role R) iff $a^{\mathcal{I}} \in C^{\mathcal{I}}$ (resp. $(a^{\mathcal{I}}, b^{\mathcal{I}}) \in R^{\mathcal{I}}$). We call *claims*, the set of concept definitions and assertions contained in the KBase. A notion of subsumption between concepts is given in terms of the interpretations. Let C, D be two concepts. C **subsumes** D (denoted $C \sqsupseteq D$) iff for every interpretation $\mathcal{I}$ its holds that
$C^{\mathcal{I}} \supseteq D^{\mathcal{I}}$. Indeed, $C \equiv D$ amounts to $C \sqsupseteq D$ and $D \sqsupseteq C$. Similarly, $C \sqcap D \equiv \perp$ amounts to $C \equiv \neg D$ and $D \equiv \neg C$. The KBase can contain partial definitions, *i.e.* axioms based on subsumption ($C \sqsupseteq D$). Below we will use $\mathcal{ALC}$ in our argumentation-based representation framework.

4 Argumentation-based representation framework

The seminal work of [3] formalizes the argumentation reasoning within a framework made of abstract arguments and a contradiction relation to determine their acceptance. We present in this section, an argumentation framework built around the underlying logic language $\mathcal{ALC}$, where claims (concept definitions and assertions) can be conflicting and have different relevances depending on the considered audience.

The KBase is a set of sentences in a common language, denoted $\mathcal{ALC}$, associated with a classical inference, denoted $\vdash$, and shared by a set of audiences (denoted $\mho_A = \{\mathrm{a}_1, \ldots, \mathrm{a}_n\}$). The audiences share a value-based KBase, *i.e.* a set of claims promoting values :

Definition 1 *Let $\mho_A = \{a_1, \ldots, a_n\}$ be a set of audiences. The* value-based KBase *$AK = \langle \mathcal{K}, V, promote \rangle$ is defined by a triple where :*
- *$\mathcal{K} = \langle \mathcal{T}, \mathcal{A} \rangle$ is a KBase, i.e. a finite set of claims in $\mathcal{ALC}$;*
- *V is a non-empty finite set of values $\{v_1, \ldots, v_t\}$;*
- *promote : $\mathcal{K} \rightarrow V$ is a total mapping from the claims to values.*

We say that the claim ϕ relates to the value v if ϕ promotes v. For every $\phi \in \mathcal{K}$, promote$(\phi) \in V$.

Values are arranged in hierarchies. For example, an audience will value both justice and utility, but an argument may require the determination of a strict preference between the two. The relevance of an argument is the value promoted by the most general claims in its premise. Since audiences are distinguished by their hierarchies of values, the values have different priorities for different audiences. Each audience a_i is associated with an *individual value-based KBase* which is a 4-tuple
$\mathrm{AK}_i = \langle \mathcal{K}, V, \mathrm{promote}, \ll_i \rangle$ where :
- $\mathrm{AK} = \langle \mathcal{K}, V, \mathrm{promote} \rangle$ is a value-based KBase as previously defined ;
- $\ll_i$ is the priority relation of the audience a_i, *i.e.* a strict complete ordering relation on V.

A priority relation is a transitive, irreflexive, asymmetric, and complete relation on V. It stratifies the KBase into finite non-overlapping sets. The priority level of a non-empty KBase $K \subseteq \mathcal{K}$ (written $\mathrm{level}_i(K)$) is the most important value promoted by one element in K. Arguments, that are consequence relations between a premise and a conclusion, are built on this common KBase.

Definition 2 *Let K be a KBase in $\mathcal{ALC}$. An **argument** is a pair $A = \langle \Phi, \phi \rangle$, where ϕ is a claim and $\Phi \subseteq K$ is a non-empty set of claims such that : Φ is consistent and minimal (for set inclusion), and $\Phi \vdash \phi$. Φ is the premise of A, written $\Phi =$*

premise(A), *and* ϕ *is the conclusion of* A, *written* $\phi = conc(A)$.

In other words, the premise is a set of claims from which the conclusion can be inferred. A' is a *sub-argument* of A if the premise of A' is included in the premise of A. A' is a *trivial argument* if the premise of A' is a singleton (premise$(A') = \{\text{conc}(A')\}$). Since the KBase $\mathcal{K}$ can be inconsistent, the set of arguments (denoted $\mathcal{A}(\mathcal{K})$) may contain conflicting arguments.

Definition 3 *Let* K *be a KBase in* $\mathcal{ALC}$ *and* $A = \langle \Phi, \phi \rangle, B = \langle \Psi, \psi \rangle \in \mathcal{A}(K)$ *two arguments.* A attacks B *iff* : $\exists \Phi_1 \subseteq \Phi, \Psi_2 \subseteq \Psi$ *such that* $\exists \chi \in \mathcal{L}$ $\Phi_1 \vdash \chi$ *and* $\Psi_2 \vdash \neg\chi$.

Because each audience is associated with a particular priority relation, audiences individually evaluate the relevance of arguments.

Definition 4 *Let* $AK_i = \langle \mathcal{K}, V, promote, \ll_i \rangle$ *be the value-based argumentation KBase of the audience* a_i *and let* $A = \langle \Phi, \phi \rangle \in \mathcal{A}(\mathcal{K})$ *be an argument. According to* AK_i*, the* relevance of A *(written* $relevance_i(A)$*) is the most important value promoted by one claim in the premise* Φ.

In other words, the relevance of arguments depends on the priority relation. A fixed ordering is simply assumed, revealing the ordering between claims. In order to give a criterion that will allow an audience to prefer one argument over another, we prefer the arguments built upon the most general claims. Since audiences individually evaluate arguments'relevance, an audience can ignore that an argument attacks another. According to an audience, an argument defeats another argument if they attack each other and the second argument is not more relevant than the first one :

Definition 5 *Let* $AK_i = \langle \mathcal{K}, V, promote, \ll_i \rangle$ *be the value-based argumentation KBase of the audience* a_i *and* $A = \langle \Phi, \phi \rangle$, $B = \langle \Psi, \psi \rangle \in \mathcal{A}(\mathcal{K})$ *two arguments.* A defeats B for the audience a_i *(written* $defeats_i(A, B)$*) iff* $\forall \Phi_1 \subseteq \Phi, \Psi_2 \subseteq \Psi$,
$(\exists \chi \in \mathcal{L},\ \Phi_1 \vdash \chi$ *and* $\Psi_2 \vdash \neg\chi) \Rightarrow \neg(level_i(\Phi_1) \ll_i level_i(\Psi_2))$.
Similarly, we say that a set S *of arguments defeats* B *if* B *is defeated by one argument in* S.

By definition, two equally relevant arguments both defeat each other.

Considering each audience own viewpoint, we define the subjective acceptance notion :

Definition 6 *Let* $AK_i = \langle \mathcal{K}, V, promote, \ll_i \rangle$ *be the value-based KBase of the audience* a_i*. Let* $A \in \mathcal{A}(\mathcal{K})$ *be an argument and* $S \subseteq \mathcal{A}(\mathcal{K})$ *a set of arguments.* A is subjectively acceptable by the audience a_i with respect to S *iff* $\forall B \in \mathcal{A}(\mathcal{K})$ $defeats_i(B, A) \Rightarrow defeats_i(S, B)$.

The following example illustrates our argumentation-based representation framework.

Example 1 *Let us consider the case presented in Section 2. The value-based KBase of two different audiences* a_1 *and* a_2 *are represented in the figure 1 and in the figure 2. The different claims* $\phi_1(x), \ldots, \phi_{72}$ *in a KBase relate to the different values* $v_1, \ldots, v_7$*. On one side, the claims* $\phi_1(x), \ldots, \phi_{61}(x)$ *are in the T-box. On the other side,* ϕ_{71} *and* ϕ_{72} *are in the A-box. The more general the claim is, the higher the promoted value is. According to an audience, a value above another one in a table has priority over it. In order to decide if acrobat is a free software, The five following arguments must be considered :*

FIG. 1 – The value-based KBase of the first audience

$\ll_1$	V_1	$\mathcal{K}_1$
	v_1	$\phi_1(x)$: Soft$(x) \sqsupseteq$ Free$(x) \sqcup$ Nonfree(x)
	v_2	$\phi_2(x)$: Nonfree$(x) \sqsupseteq$ Freeware(x)
	v_3	$\phi_3(x)$: Free$(x) \sqsupseteq$ Freeware(x)
	v_4	$\phi_4(x)$: Free$(x) \sqcap$ Nonfree$(x) \equiv \perp$
	v_5	$\phi_5(x)$: Free$(x) \sqsupseteq$ Opensource(x)
	v_6	$\phi_{61}(x)$: Opensource$(x) \sqsupseteq$ Copyleft(x)
	v_7	ϕ_{71} : Freeware(acrobat) ϕ_{72} : Copyleft(xpdf)

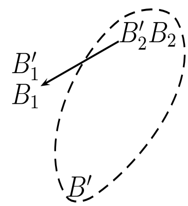
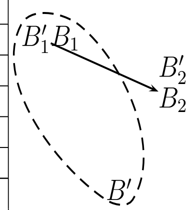


FIG. 2 – The value-based KBase of the second audience

$\ll_2$	V_2	$\mathcal{K}_2$
	v_1	$\phi_1(x)$: Soft$(x) \sqsupseteq$ Free$(x) \sqcup$ Nonfree(x)
	v_3	$\phi_3(x)$: Free$(x) \sqsupseteq$ Freeware(x)
	v_2	$\phi_2(x)$: Nonfree$(x) \sqsupseteq$ Freeware(x)
	v_4	$\phi_4(x)$: Free$(x) \sqcap$ Nonfree$(x) \equiv \perp$
	v_5	$\phi_5(x)$: Free$(x) \sqsupseteq$ Opensource(x)
	v_6	$\phi_{61}(x)$: Opensource$(x) \sqsupseteq$ Copyleft(x)
	v_7	ϕ_{71} : Freeware(acrobat) ϕ_{72} : Copyleft(xpdf)



– $B' = \langle[$*Freeware*$($*acrobat*$)],$ *Freeware*$($*acrobat*$)\rangle$ *;*
– $B'_1 = \langle[$*Freeware*$($*acrobat*$),$ *Free*$(x) \sqsupseteq$ *Freeware*$(x))],$ *Free*$($*acrobat*$)\rangle$ *;*
– $B'_2 = \langle[$*Freeware*$($*acrobat*$),$ *Nonfree*$(x) \sqsupseteq$ *Freeware*$(x))],$ *Nonfree*$($*acrobat*$)\rangle$ *;*
– $B_1 = \langle[$*Freeware*$($*acrobat*$),$ *Free*$(x) \sqsupseteq$ *Freeware*$(x),$ *Free*$(x) \sqcap$ *Nonfree*$(x) \equiv \perp],$ $\neg$*Nonfree*$($*acrobat*$)\rangle$ *;*
– $B_2 = \langle[$*Freeware*$($*acrobat*$),$ *Nonfree*$(x) \sqsupseteq$ *Freeware*$(x),$ *Free*$(x) \sqcap$ *Nonfree*$(x) \equiv \perp],$ $\neg$*Free*$($*acrobat*$)\rangle$ *;*

B' is a sub-argument of B'_1 (resp. B'_2) which is a sub-argument of B_1 (resp. B_2). B_1 and B'_2 (resp. B'_1 and B_2) attack each other. The relevance of B_1 and B'_1 is v_3. The relevance of B_2 and B'_2 is v_2. According to the first audience, B'_2 (resp. B_2) defeats B_1 (resp. B'_1) but B_1 (resp. B'_1) does not defeat B'_2 (resp. B_2). Therefore, the set $\{B', B'_2, B_2\}$ is subjectively acceptable wrt $\mathcal{A}(\mathcal{K})$. According to the second audience, B_1 (resp. B'_1) defeats B'_2 (resp. B_2) but B'_2 (resp. B_2) does not defeat B_1 (resp. B'_1). Therefore, the set $\{B, B'_1, B_1\}$ is subjectively acceptable wrt $\mathcal{A}(\mathcal{K})$.

We have defined here the representation framework to manage interactions between conflicting claims. In the next section, we present a model of agents which puts forward claims and takes into account other claims coming from their interlocutors.

5 Model of agents

In a multi-agent setting it is natural to assume that all the agents do not use exactly the same ontology. Since agents representations can be common, complementary or contradictory, agents have to exchange assumptions and to argue. Our agents individually evaluate the perceived commitments with respect to the estimated reputation of the agents from whom the information is obtained.

Agents, which have their own private representations, record their interlocutors commitments. Moreover, agents individually valuate their interlocutors reputation. Therefore, an agent is defined as follows :

Definition 7 *The* agent $a_i \in \mho_A$ *is defined by a 6-tuple*
$a_i = \langle \mathcal{K}_i, V_i, \ll_i, promote_i, \cup_{j \neq i} CS^i_j, \prec_i \rangle$
where :

- $\mathcal{K}_i$ *is a personal KBase, i.e. a set of personal claims in* $\mathcal{ALC}$ *;*
- V_i *is a set of personal values ;*
- $promote_i : \mathcal{K}_i \rightarrow V_i$ *maps from the personal claims to the personal values ;*
- $\ll_i$ *is the priority relation, i.e. a strict complete ordering relation on* V_i *;*
- CS^i_j *is a commitment store, i.e. a set of claims in* $\mathcal{ALC}$*.* $CS^i_j(t)$ *contains propositional commitments taken before or at time* t*, where agent* a_j *is the debtor and agent* a_i *the creditor ;*
- $\prec_i$ *is the reputation relation, i.e. a strict complete ordering relation on* $\mho_A$*.*

The personal KBases are not necessarily disjoint. The commonsense claims are explicitly shared by all the agents. We call *common KBase* the set of commonsense claims explicitly shared by the agents[1] : $\mathcal{K}_{\Omega_A} \subseteq \cap_{a_i \in \mho_A} \mathcal{K}_i$. Similarly, we call *common values* the values explicitly shared by the agents : $V_{\Omega_A} \subseteq \cap_{a_i \in \mho_A} V_i$. The common claims relate to the common values. For every $\phi \in \mathcal{K}_{\Omega_A}$, $\text{promote}_{\Omega_A}(\phi) = v \in V_{\Omega_A}$. The personal KBase can be complementary or contradictory. Some claims can be shared without the agents being aware of it. These similarities between agents will be discovered during the dialogue. We call *joint KBase* the set of claims distributed in the system : $\mathcal{K}_{\mho_A} = \cup_{a_i \in \mho_A} \mathcal{K}_i$. The agent's own claims relate to the agent's own values. For every $\phi \in \mathcal{K}_i - \mathcal{K}_{\Omega_A}$, $\text{promote}_i(\phi) = v \in V_i - V_{\Omega_A}$.

[1] We qualify with Ω_A a value obtained through an intersection over $\mho_A$

Reputation is a local perception of the interlocutor, a social concept that links an agent to her interlocutors, and a leveled relation. The different reputation relations, which are transitive, irreflexive, asymmetric, and complete relations on $\mho_A$, preserve these properties. $a_j \prec_i a_k$ denotes that an agent a_i trusts an agent a_k more than another agent a_j. In order to take into account the claims notified in the commitment stores, each agent is associated with the following extended KBase :

Definition 8 *The* extended KBase of the agent a_i *is the value-based KBase*
$AK^*_i = \langle \mathcal{K}^*_i, V^*_i, promote^*_i, \ll^*_i \rangle$ *where :*

- $\mathcal{K}^*_i = \mathcal{K}_i \cup [\bigcup_{j \neq i} CS^i_j]$ *is the agent extended personal KBase composed of its personal KBase and the set of perceived commitments ;*
- $V^*_i = V_i \cup [\bigcup_{j \neq i} \{v^i_j\}]$ *is the agent extended set of personal values composed of the set of personal values and the reputation values associated with her interlocutors ;*
- $promote^*_i : \mathcal{K}^*_i \rightarrow V^*_i$ *is the extension of the function* $promote_i$ *mapping claims in the extended personal KBase to the extended set of personal values. On the one hand, personal claims relate to personal values. On the other hand, claims in the commitment store* CS^i_j *relate to the reputation value* v^i_j *;*
- $\ll^*_i$ *is the agent extended priority relation, i.e. an ordered relation on* V^*_i*.*

Since the debate is a collaborative social process, agents share common claims of prime importance. That is the reason why we consider that the common values have priority over the other values.An agent a_1 may estimate herself more competent than her interlocutor a_2 and her personal values have priority over v_2^1, i.e. the reputation value of the agent a_2. In this case, the extended priority relation of the agent a_1 is constrained as follows : $\forall v_\omega \in V_{\Omega_A} \forall v \in V_1 - V_{\Omega_A}$ $(v_2^1 \lll_1^* v \lll_1^* v_\omega)$. We can easily demonstrate that the extended priority relation is a strict complete ordering relation. The one-agent notion of conviction is then defined as follows :

Definition 9 *Let $a_i \in \mho_A$ be an agent associated with the extended KBase $AK_i^* = \langle \mathcal{K}_i^*, V_i^*, promote_i^*, \lll_i^* \rangle$ and let $\phi \in \mathcal{ALC}$ be a claim. The* agent a_i is convinced by the claim ϕ *iff ϕ is the conclusion of an acceptable argument for the audience a_i with respect to $\mathcal{A}(\mathcal{K}_i^*)$. The set of acceptable arguments for the audience a_i with respect to $\mathcal{A}(\mathcal{K}_i^*)$ is denoted by $\mathcal{S}_i^*$.*

Let us know consider how claims are produced. Agents utter messages to exchange their representations. The syntax of messages is in conformance with the common *communication language*, $\mathcal{CL}$. A message $M_k = \langle S_k, H_k, A_k \rangle \in \mathcal{CL}$ has an identifier M_k. It is uttered by a speaker ($S_k = \text{speaker}(M_k)$) and addressed to an hearer ($H_k = \text{hearer}(M_k)$). $A_k = \text{act}(M_k)$, the message speech act, is composed of a locution and a content. The locution is one of the following : `question, request assert, propose, refuse, unknow, concede, challenge, withdraw`. The content, also called *assumption*, is a claim or a set of claims in $\mathcal{ALC}$.

Speech acts have a public semantic, since commitments enrich the extended KBase of the creditors, and an argumentative semantic, since commitments are justified by the extended KBase of the debtor. For example, Figure 3 shows the semantics associated with the assertion of an assumption. An agent can propose an assumption if she has an argument for it. The corresponding commitments stores are updated. The speech act `propose` has the same argumentative/public semantics. `refuse`(ϕ) is equivalent to `assert`$(\neg\phi)$. As we will see in Section 7, these latter do not have the same place in the sequence. The rational conditions for the assertion and for the concession of the same assumption by the same agent are different. Agents can assert an assumption whether they are supported by a trivial argument or not. By contrast, agents do not concede all the assumptions they hear in spite of all assumptions are supported by a trivial argument.

The others speech acts (`question`, `request`, `unknow`, `challenge`, and `withdraw`) are used to manage the sequence of moves (see Section 7). They have no particular effects on commitments stores, neither particular rational conditions of utterance. We assume that the commitments stores are cumulative, *i.e.* no commitment can be retracted. This is the reason why the speech act `withdraw`(h) has no effect on the commitments stores.

The assumptions which are received must be valuated. For this purpose, commitments will be individually considered in accordance with the speaker estimated reputation. The following example illustrates this principle.

Example 2 *Let us consider two agents, a service provider (denoted prov) and a customer (denoted cust). It is worth recalling that the service provider considers that customer's claims make authority and adjust her own representation to adopt these claims. The initial personal KBase of the service provider is the set $\{\phi_1(x), \phi_3(x)\phi_4(x), \phi_5(x), \phi_{61}(x), \phi_{71}, \phi_{72}\}$ and the personal KBase of the customer is the set $\{\phi_1(x), \phi_2(x), \phi_4(x), \phi_{62}(x)\}$. If the customer utters the two following messages :*

– $M_1 = \langle cust, prov,$ `assert`$(\neg Free(acrobat)) \rangle$,

FIG. 3 – Semantics for asserting an assumption ϕ at time t

- MESSAGE : $M_l = \langle \mathrm{a}_i, \mathrm{a}_j, \texttt{assert}(\phi) \rangle$
  - ARGUMENTATIVE SEMANTICS : $\exists A \in \mathcal{A}(\mathcal{K}_i^*)\ \mathrm{conc}(A) = \phi$
  - PUBLIC SEMANTICS : For any agent a_k in the audience if $\phi \notin \mathcal{A}(\mathcal{K}_\mathrm{k}^*)$ then $\mathrm{CS}_i^k(t) = \mathrm{CS}_i^k(t-1) \cup \{\phi\}$

– $M_2 = \langle cust, prov,$ $\texttt{assert}(\phi_2(acrobat), \phi_4(acrobat), \phi_{71}) \rangle$.

then the extended KBase of the service provider is represented as in Table 1. The extended KBase of the service provider is composed of her personal claims and the claims advanced by the customer. The extended set of personal values is composed of the set of personal values and the reputation value of the customer. The common claim $\phi_1(x)$ is related to the common value v_1. The claims in the commitments is related to the reputation value of the customer. By uttering the message M_1, the customer advances the trivial argument $B_3 = \langle [\neg Free(acrobat)], \neg Free(acrobat) \rangle$. *Despite the service provider is convinced by this assumption, she cannot concede it. Indeed, this assumption is only supported by a trivial argument in the commitment stores. By uttering the message M_2, the customer advances the non-trivial argument B_2 bearing on the service provider own claims. Therefore, this last one can concede $\neg Free(acrobat)$. The only free software she can propose is xpdf.*

We have presented here a model of agents who exchange assumptions and argue. In the next section, we provide a dialectical system where debates take place.

6 Dialectical system

When a set of social and autonomous agents argue, they reply to each other in order to reach the goal of the interaction. We provide a dialectical system, which is inspired by [7] and adapted to the dialogue on representations.

During exchanges, the speech acts are not isolated but they respond each other. The syntax of moves is in conformance with the common *moves language* : $\mathcal{ML}$ defined as follows : a move $\mathrm{move}_k = \langle M_k, R_k, P_k \rangle \in \mathcal{ML}$ has an identifier move_k. It contains a message M_k as defined before. The moves are messages with some attributes to control the sequence. $R_k = \mathrm{reply}(\mathrm{move}_k)$ is the identifier of the move to which move_k responds. A move (move_k) is either an initial move ($\mathrm{reply}(\mathrm{move}_k) = \mathrm{nil}$) or a replying move ($\mathrm{reply}(\mathrm{move}_k) \neq \mathrm{nil}$). $\mathrm{P}_k = \mathrm{protocol}(\mathrm{move}_k)$ is the name of the protocol which is used during the dialogue.

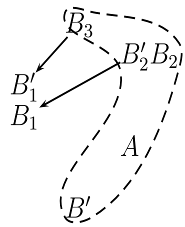
A dialectical system is composed of two agents. In this formal area, two agents play moves to check an initial assumption, *i.e.* the topic.

Definition 10 *Let* $AK_{\Omega_A} = \langle \mathcal{K}_{\Omega_A}, V_{\Omega_A}, promote_{\Omega_A} \rangle$ *be a common value-based KBase and ϕ_0 a claim in $\mathcal{ALC}$. The* ***dialectical system*** *on the topic ϕ_0 is a quintuple* $DS_{\Omega_M}(\phi_0, AK_{\Omega_A}) = \langle N, H, T, protocol, Z \rangle$ *where :*

- $N = \{init, part\} \subset \mho_A$ *is a set of two agents called players : the initiator and the partner ;*
- H *is the set of histories, i.e. the sequences of well-formed moves s.t. the speaker of a move is determined at each stage by a turn-taking function and the moves agree with a protocol ;*
- $T : H \rightarrow N$ *is the turn-taking function determining the speaker of a move. If* $|h| = 2n$ *then* $T(h) = init$ *else* $T(h) = part$ *;*

TAB. 1 – The extended KBase of the service provider

$\ll^*_{\text{prov}}$	V^*_{prov}	$\mathcal{K}^*_{\text{prov}}$
$\uparrow$	v_1	$\phi_1(x)$: Soft$(x) \sqsupseteq$ Free$(x) \sqcup$ Nonfree(x)
	$v^{\text{prov}}_{\text{cust}}$	$\text{CS}^{\text{prov}}_{\text{cust}} = \{\neg$Free(acrobat), ϕ_2(acrobat) : Nonfree(acrobat) $\sqsupseteq$ Freeware(acrobat)$\}$
	v_3	$\phi_3(x)$: Free$(x) \sqsupseteq$ Freeware(x)
	v_4	$\phi_4(x)$: Free$(x) \sqcap$ Nonfree$(x) \equiv \perp$
	v_5	$\phi_5(x)$: Free$(x) \sqsupseteq$ Opensource(x)
	v_6	$\phi_{61}(x)$: Opensource$(x) \sqsupseteq$ Copyleft(x)
	v_7	ϕ_{71} : Freeware(acrobat) ϕ_{72} : Copyleft(xpdf)



– *protocol* : $H \rightarrow \Omega_M$ *is the function determining the moves which are allowed or not to expand an history, where* $\Omega_M \subseteq \mathcal{ML}$ *is the set of all well-formed moves ;*
– Z *is the set of dialogue, i.e. terminal histories.*

In order to be well-formed, the initial move is a question about the topic from the initiator to the partner and a replying move from a player always references an earlier move uttered by the other player. In this way, backtracking are allowed. We call dialogue line the sub-sequence of moves where all backtracks are ignored. In order to avoid loops, assumptions redundancy is forbidden within assertions.

We have bound here the area in which dialogues take place. We formalize in the next section a particular protocol to reach a representation agreement.

7 Protocol

When two agents have a dialogue, they collaborate to reconcile their representations. For this purpose, we propose in this section a protocol.

A protocol is determinated by a set of sequence rules (see Table 2). Each rule specifies authorized replying moves. According to the "Question/Answer" rule ($\text{sr}_{Q/A}$), the hearer of a question (`question`(ϕ)) is allowed to respond with a confirmation (`assert`(ϕ)), or with an invalidation (`assert`$(\neg\phi)$), or with a plea of ignorance (`unknow`(ϕ)). The "Request/Propose" rule ($\text{sr}_{R/P}$) is quite similar. The hearer of a request (`request`$(\phi(x))$) is allowed to respond either by asserting an instantiation of this assumption (`assert`$(\phi(a))$), or with a plea of ignorance (`unknow`$(\phi(x))$). The respond can resist or surrender to the previous speech act. For example, the "Assert/Welcome" rule (written $\text{sr}_{A/W}$) specifies authorized moves replying to the previous assertions (`assert`(Φ)). Contrary to resisting acts, surrendering acts close the dialogue line. A concession (`concede`(Φ)) surrenders to the previous proposition. A challenge (`challenge`(ϕ)) and a refuse (`refuse`(ϕ)) resist to the previous proposition.

We consider here the requesting multi-response persuasion protocol (denoted ReqMultiResPersProto) using the following rules : $\text{sr}_{R/P}$, $\text{sr}_{A/W}$, and $\text{sr}_{C/A}$. In order to enrich her representation with a partner, an initiator begins a dialogue with a request in the game situation 0^{init}. If the partner has no representation for the topic, she pleads ignorance and closes the dialogue (see game situation $2.1^{\square}$). The goal of the dialogue is to reach an agreement

TAB. 2 – Set of speech acts and their potential answers.

Sequences rules	Speech acts	Resisting replies	Surrendering replies
$\text{sr}_{Q/A}$	`question`(ϕ)	`assert`(ϕ) `assert`$(\neg\phi)$	`unknow`(ϕ)
$\text{sr}_{R/P}$	`request`$(\phi(x))$	`propose`$(\phi(a))$	`unknow`$(\phi(x))$
$\text{sr}_{A/W}$	`assert`(Φ)	`challenge`$(\phi), \phi \in \Phi$ `refuse`$(\phi), \phi \in \Phi$	`concede`(Φ)
$\text{sr}_{C/A}$	`challenge`(ϕ)	`assert`$(\Phi), \Phi \vdash \phi$	`withdraw`(ϕ)

over representations by verbal means. The following example illustrates such a dialogue.

Example 3 *Let us consider again the dialogue presented in Section 2. Table 3 shows how, using the protocol, the two agents play the dialogue. This table details the different moves corresponding to the claims of the natural language dialogue. We can see that the commitments stores are the results of moves. At the beginning of the dialogue,* ϕ_1 *is the only claims explicitly shared by the agents (*$\mathcal{K}_{\Omega_A}$*). During exchanges, the service provider detects that she shares* ϕ_4 *with the customer. At the end of the dialogue, the set of claims explicitly shared increases. In other terms, the agents co-build a common ontology during the dialogue.*

8 Related works

[6] provides a framework for agents to reach an agreement over ontology alignment. Argumentation is used to select a correspondence among candidate correspondences, according to the ontological knowledge and the agents' preferences. This approach is static because alignments have been achieved off-line. [10] proposes the ANEMONE approach for solving semantic integration problems. Instead of trying to solve ontology problems at design time, ANEMONE provides agents with tools to overcome ontology problems at agent interaction time and focus on the layered communication mechanism. [9] proposes a framework to solve on-line the semantic heterogeneity by exploiting the topological properties of the representation. This work considers one-shot interaction steps. As we have already said, we have extended the formal framework for inter-agents dialogue based upon the argumentative techniques proposed by [7]. Since the denotational semantics of the description logic is adapted to the knowledge representation, the background logic has shift from the first order logic program to the description logic.

9 Conclusion

In this paper, we have proposed a framework for inter-agents dialogue to reach an agreement, which formalizes a debate in which divergent representations are discussed. For this purpose, we have proposed an argumentation-based representation framework which manages the conflicts between claims with different relevances for different audiences to compute their acceptance. Moreover, we have proposed a model for the reasoning of agents where they justify the claims to which they commit and take into account the claims of their interlocutors. We provide a dialectical system in which two agents participate in a dialogue to reach an agreement about a conflict in representations. In this work, we have focused on multi-agent systems but, as suggested by the example, our approach is also relevant to the Semantic Web, where different services performing

TAB. 3 – Dialogue to reach an agreement. Natural language sentences, corresponding to the dialogue presented in 2, are given in association with their dialogue , then the new the commitment stores and the reached game situation are given.

<table>
<tr><td colspan="2">$\mathcal{K}^*_{\text{cust}} - \mathcal{K}_{\Omega_A}$</td><td>$\mathcal{K}_{\Omega_A}$
ϕ_1</td><td colspan="2">$\mathcal{K}^*_{\text{prov}} - \mathcal{K}_{\Omega_A}$</td></tr>
<tr><td>$\mathcal{K}_{\text{cust}}$</td><td>$\text{CS}^{\text{cust}}_{\text{prov}}$</td><td>Game situation</td><td>$\text{CS}^{\text{prov}}_{\text{cust}}$</td><td>$\mathcal{K}_{\text{prov}}$</td></tr>
<tr><td>$\phi_2(x), \phi_4(x)$
$\phi_{62}(x)$.</td><td>$\emptyset$</td><td>0^{cust}</td><td>$\emptyset$</td><td>$\phi_3(x), \phi_4(x), \phi_5(x)$,
$\phi_{61}(x), \phi_{71}, \phi_{72}$.</td></tr>
<tr><td colspan="5">Do you know free software to view my PDF ?
$\rightarrow \text{move}_1 = \langle \text{cust, prov, } \texttt{request}(\text{Free}(x)), \text{nil, ReqMultiResPersProto} \rangle \rightarrow$</td></tr>
<tr><td>idem</td><td>$\emptyset$</td><td>1^{prov}</td><td>$\emptyset$</td><td>idem</td></tr>
<tr><td colspan="5">acrobat is free software.
$\leftarrow \text{move}_2 = \langle \text{prov, cust, } \texttt{propose}(\text{Free}(\text{acrobat})), \text{move}_1, \text{ReqMultiResPersProto} \rangle \leftarrow$</td></tr>
<tr><td>idem</td><td>Free(acrobat)</td><td>2.2^{cust}</td><td>$\emptyset$</td><td>idem</td></tr>
<tr><td colspan="5">Why is it free software ?
$\rightarrow \text{move}_3 = \langle \text{cust, prov, } \texttt{challenge}(\text{Free}(\text{acrobat})), \text{move}_2, \text{ReqMultiResPersProto} \rangle \rightarrow$</td></tr>
<tr><td>idem</td><td>Free(acrobat)</td><td>3.3^{prov}</td><td>$\emptyset$</td><td>idem</td></tr>
<tr><td colspan="5">acrobat is free because this is freeware.
$\leftarrow \text{move}_4 = \langle \text{prov, cust, } \texttt{assert}(\phi_3(\text{acrobat}), \phi_{71}), \text{move}_3, \text{ReqMultiResPersProto} \rangle \leftarrow$</td></tr>
<tr><td>idem</td><td>Free(acrobat), ϕ_3(acrobat), ϕ_{71}</td><td>4.3^{cust}</td><td>$\emptyset$</td><td>idem</td></tr>
<tr><td colspan="5">In my humble opinion, acrobat is not free software.
$\rightarrow \text{move}_5 = \langle \text{cust, prov, } \texttt{refuse}(\text{Free}(\text{acrobat})), \text{move}_2, \text{ReqMultiResPersProto} \rangle \rightarrow$</td></tr>
<tr><td>idem</td><td>Free(acrobat), ϕ_3(acrobat), ϕ_{71}</td><td>3.1^{prov}</td><td>$\neg$Free(acrobat)</td><td>idem</td></tr>
<tr><td colspan="5">Why is it not free software ?
$\leftarrow \text{move}_6 = \langle \text{prov, cust, } \texttt{challenge}(\neg\text{Free}(\text{acrobat})), \text{move}_5, \text{ReqMultiResPersProto} \rangle \leftarrow$</td></tr>
<tr><td>idem</td><td>Free(acrobat), ϕ_3(acrobat), ϕ_{71}.</td><td>4.1^{cust}</td><td>$\neg$Free(acrobat).</td><td>idem</td></tr>
<tr><td colspan="5">Since acrobat is freeware, this is not free software.
$\rightarrow \text{move}_7 = \langle \texttt{assert}(\phi_2(\text{acrobat}), \phi_4(\text{acrobat}), \phi_{71}), \text{move}_6, \text{ReqMultiResPersProto} \rangle \rightarrow$</td></tr>
<tr><td>idem</td><td>Free(acrobat), ϕ_3(acrobat), ϕ_{71}.</td><td>5.2^{prov}</td><td>$\neg$Free(acrobat), ϕ_2(acrobat).</td><td>idem</td></tr>
<tr><td colspan="5">OK, however xpdf is free software.
$\leftarrow \text{move}_8 = \langle \text{prov, cust, } \texttt{propose}(\text{Free}(\text{xpdf})), \text{move}_1, \text{ReqMultiResPersProto} \rangle \leftarrow$</td></tr>
<tr><td>idem</td><td>Free(acrobat), ϕ_3(acrobat), ϕ_{71},
Free(xpdf).</td><td>2.2^{cust}</td><td>$\neg$Free(acrobat), ϕ_2(acrobat).</td><td>idem</td></tr>
<tr><td colspan="5">Why is it free software ?
$\rightarrow \text{move}_9 = \langle \text{cust, prov, } \texttt{challenge}(\text{Free}(\text{xpdf})), \text{move}_8, \text{ReqMultiResPersProto} \rangle \rightarrow$</td></tr>
<tr><td>idem</td><td>Free(acrobat), ϕ_3(acrobat), ϕ_{71},
Free(xpdf).</td><td>3.3^{prov}</td><td>$\neg$Free(acrobat), ϕ_2(acrobat).</td><td>idem</td></tr>
<tr><td colspan="5">xpdf is free software because it is opensource.
$\leftarrow \text{move}_{10} = \langle \text{prov, cust, } \texttt{assert}(\text{Opensource}(\text{xpdf}), \phi_5(\text{xpdf}))\rangle, \text{move}_9, \text{ReqMultiResPersProto} \rangle \leftarrow$</td></tr>
<tr><td>idem</td><td>Free(acrobat), ϕ_3(acrobat), ϕ_{71},
Free(xpdf), Opensource(xpdf), ϕ_5(xpdf).</td><td>4.3^{cust}</td><td>$\neg$Free(acrobat), ϕ_2(acrobat).</td><td>idem</td></tr>
<tr><td colspan="5">Why is it opensource ?
$\rightarrow \text{move}_{11} = \langle \text{prov, cust, } \texttt{challenge}(\text{Opensource}(\text{xpdf})), \text{move}_{10}, \text{ReqMultiResPersProto} \rangle \rightarrow$</td></tr>
<tr><td>idem</td><td>Free(acrobat), ϕ_3(acrobat), ϕ_{71},
Free(xpdf), Opensource(xpdf), ϕ_5(xpdf).</td><td>5.5^{prov}</td><td>$\neg$Free(acrobat), ϕ_2(acrobat).</td><td>idem</td></tr>
<tr><td colspan="5">xpdf is opensource because it is copyleft.
$\leftarrow \text{move}_{12} = \langle \text{prov, cust, } \texttt{assert}(\phi_{72}(\text{xpdf}), \phi_{61}(\text{xpdf})), \text{move}_{11}, \text{ReqMultiResPersProto} \rangle \leftarrow$</td></tr>
<tr><td>idem</td><td>Free(acrobat), ϕ_3(acrobat), ϕ_{71},
Free(xpdf), Opensource(xpdf), ϕ_5(xpdf),
ϕ_{72}(xpdf), ϕ_{61}(xpdf).</td><td>6.2^{cust}</td><td>$\neg$Free(acrobat), ϕ_2(acrobat).</td><td>idem</td></tr>
<tr><td colspan="5">OK, I will consider xpdf ?
$\rightarrow \text{move}_{13} = \langle \text{prov, cust, } \texttt{concede}(\text{Free}(\text{xpdf})), \text{move}_8, \text{ReqMultiResPersProto} \rangle \rightarrow$</td></tr>
<tr><td>idem</td><td>Free(acrobat), ϕ_3(acrobat), ϕ_{71},
Free(xpdf), Opensource(xpdf), ϕ_5(xpdf),
ϕ_{72}(xpdf), ϕ_{61}(xpdf).</td><td>$3.2^{\square}$</td><td>$\neg$Free(acrobat), ϕ_2(acrobat),</td><td>idem</td></tr>
</table>

the same tasks may advertise their capabilities differently, or where service requests, and service offers may be expressed by using different ontologies, and thus need to be reconciled dynamically at run time. While this work focuses on single dialogues between two heterogeneous agents, future investigations must explore how this solution, when it will be implemented, scales to multi-agent systems where dialogues are amongst multiple parties and sequenced.

Acknowledgements

The authors like to thank Yann Secq, Jean-Paul Sansonnet, and Philippe Mathieu for their willingness to discuss this issue with us. Thanks are also due to Fariba Sadri and Paolo Mancarella for their advice to improve the English of this paper. We would like to thank the anonymous reviewers for their detailed comments on this paper. The first author is supported by the Sixth Framework IST programme of the EC, under the 035200 ARGUGRID project. The second author is supported by the CPER TAC of the region Nord-Pas de calais and the european fund FEDER.

Références

[1] S. Bailin and W. Truszkowski *Ontology negotiation between intelligent information agents* Knowledge Engineering Review, **17**(1), pages 7–19, Cambridge University Press (2002).

[2] T.J.M Bench-Capon. *Value based argumentation frameworks*. In Proceedings of NMR'02, pages 444–453, Toulouse, France (2002).

[3] Phan Minh Dung. *On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games* Artificial Intelligence, **77**(2), pages 321–357, Springer-Verlag (1995).

[4] Jérôme Euzenat and Petko Valtchev *Similarity-Based Ontology Alignment in OWL-Lite* in Proc. of ECAI, pages 333-337, IOS Press (2004).

[5] Thomas R. Gruber *Toward principles for the design of ontologies used for knowledge sharing* International Journal of Human-Computer Studies, **43**(5-6), pages 907–928, Academic Press (1995).

[6] Loredana Laera Valentina Tamma, Jérôme Euzenat, Trevor Bench-Capon and Terry Payne *Reaching agreement over ontology alignments.* In Proc. of ISWC, pages 371-384, Springer-Verlag (2006).

[7] Maxime Morge *Collective decision making process to compose divergent interests and perspectives* Artificial Intelligence and Law, **13**(1), pages 75-92, Springer-Verlag, (2005).

[8] Schmidt-Schauß M. and Smolka, G. *Attributive concept descriptions with complements* Artificial Intelligence, **48**(1), pages 1–26, Springer-Verlag (1991).

[9] Erika Valencia and Jean-Paul Sansonnet *Building Semantic Channels between Heterogeneous Agents with Topological Tools* In Proc. of ESAW, Barcelona, Spain (2004).

[10] Van Digglen Jurriaan, Beun Robbert-Jan, Dignum Frank, Van Eijk Rogier and Meyer John-Jules *Anemone : An effective minimal ontology negotiation environment* In Proc. of AAMAS, pages 899–906, ACM Press (2006).

[11] Douglas N. Walton and Eric C. W. Krabbe *Commitment in Dialogue*, SUNY Press (1995).